Variations of run-up on Vertical and Curved Seawall Models under Regular, Random and Cnoidal Waves

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Abstract— **The shoreline erosion is a major problem that persist world wide and seawall still remain as one of the most widely adopted coastal protection structure. The design of an efficient seawall should be such that overtopping is minimized even during coastal flooding and extreme events by maintaining its crest elevation as low as possible. This can be obtained with curved front face sea walls, with background an experimental investigation on run-up over a vertical faced seawall and a curved face seawall given in Coastal Engineering Manual suggested by US ARMY CORPS were placed over a bed slope of 1 in 30 and subjected to the action of regular, random and cnoidal waves was carried out. The results of both the models were compared and discussed.**

Index Terms— **Seawalls, run-up, cnoidal waves, coastalprotection, regular and random waves**

I. Introduction

The seawalls are the most common coastal protection structure built along the shoreline parallel to the beach to protect the shoreline from erosion. The dissipation of the incident energy in a coastal structure is mostly due to loss of kinetic energy in the waves running over the front slope of the structure and due to partial reflection. Although the run-up is less requiring lower crest elevation, the vertical front face seawall experience high reflection almost close to unity resulting in more forces and scour near its toe. Further, reflection in general is not preferred as the wave climate in its immediate vicinity on its seaside is almost twice which also sometimes questions its stability. During the ingress of storms and extreme waves, the crest elevation has to necessarily be higher in order to avoid overtopping. In order to dissipate the incident wave energy gradually through shoaling, sloping walls were introduced. Although more stable, (Granthem., 1953) reported that for a given incident wave height the maximum run-up occurred for a slope angle of 30º and that if there was any variation from that slope in either direction, the wave run-up would decrease. (Kirkgoz., 1991; Muller and Whittaker., 1993) reported that the impact pressures and the resulting forces on sloping walls are greater than those on vertical walls. The sloping walls are not desirable, since it experiences high pressures and run-up and thus requiring higher crest elevation and further it occupies more space compared to that of a vertical seawall. Hence, it is evident a coastal protection measure should be effective with an optimum use of the coastal space, with less or no wave overtopping by maintaining a lower crest elevation. This in fact can also enhance the scenic beauty of the oceanic view. This objective may be achieved by considering a front shape of the structure, which forms the main objective of the present study. This objective may be achieved by considering a front shape of the structure, which forms the main objective of the present study. Weber, (1934) has given a conceptual design of curved seawall with a combination of a parabolic and a circular arc which brings a smooth change in the direction of propagation from horizontal to vertical and vise versa to reduce the wave induced pressures. Murakami *et al.,* (1996) proposed a new type of circular arc non-over topping seawall and measured the pressures and forces due to regular waves. It was concluded that the critical crest elevation was much less compared to that for a vertical seawall. The pressures were reported to be a function of the ratio of water depth, d to wave height, H with its maximum occurring closer to the still water level. Kamikubo *et al.*, (2000) investigated the characteristics of the curved seawall and the fluid flow near the seawall was reproduced through numerical simulation using finite volume method. The results obtained were almost similar to that of Murakami *et al.*, (1996). Similar study was reported by Kamikubo *et al.,* (2002 and 2003) along with the investigation on the spray when the waves strike the wall. Murakami *et al.*, (2008) reported the efficiency of a curved seawall under increased water level due to global warming. The review of literature reveals that a variety of configurations of curved sea front walls have been suggested and some of which have also found its application in the field. The literature on curved front seawall is scanty and is limited, which mostly pertain to regular waves.

II. Experimental investigation

This study deals with a comprehensive experimental investigation on the run-up over the vertical and a curved sea wall due to regular, random and Cnoidal waves propagating over a sloping bed of 1 in 30. The tests have been carried out in two different water depths of 0.88m and 1m in a 72.5m long and 2m wide wave flume in Department of Ocean Engineering, IIT Madras, by adopting a model scale of 1:5.

The models considered for the study are, model(VW) vertical wall and model(GS) curved front seawall with a combination of two radii of curvature as suggested in Coastal Engineering Manual by US Army Corps of Engineers (2006), which has been adopted at Galveston, Texas, USA,

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constructed during 1905. The models were fabricated with Fiber Reinforced Plastic (FRP). The geometries of the seawall models considered under the present study are projected in Fig. 1**.** The test set-up consisted of a rigid partition wall along the length of the flume over the adopted bed slope of 1:30 in order to facilitate simultaneous testing of two cross sections in the flume. The toe of the model was placed at a distance of 40m from the wave maker. The test set up in the flume both in plan and sectional elevation are projected in Figure 2. The sections were exposed to the action of regular waves with period between 1 and 3 sec at an interval of 0.4sec with wave heights of 0.05, 0.1m -0.26m at 0.04m interval. The sections were also exposed to random waves described by Pierson-Moskowitz (PM) spectrum, with peak frequency ranging from 0.33 Hz to 1.0 Hz (ie peak period ranging between 1 and 3 sec with an interval of 0.4sec with each of the period) associated with at least three significant wave heights, and 0.22m. in addition to regular and random waves, Cnoidal waves with period ranging between 3 and 12 sec, each of which was associated with a wave height of 0.05m, 0.1m and 0.15m, thus covering a wide range of Ursell's parameter (L^2H/d^3) from 4 to 301 were employed for the tests. Herein, L, H and d are the wave length, wave height and water depth respectively.

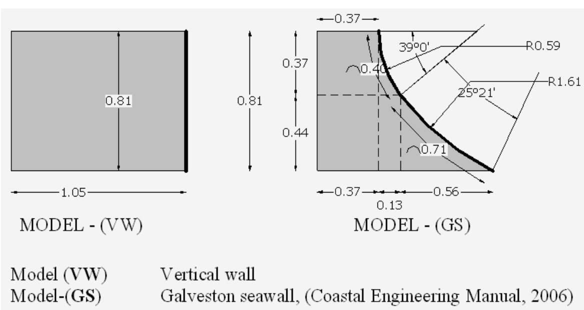

Fig. 1 The geometries of the seawall models considered under the present study

III. Results And Discussions

A. Run-up under regular waves

The variations of relative run-up (R_u/H) as a function of d/L for models (VW) and (GS) with their toe in a water depth of 0.46m are plotted in Fig. 3(a) for *H/d* values of 0.108 to 0.478. The R_u/H in general is found to decrease with an increase in *d/L*. A comparison of the results for models (VW) and (GS) exhibit that run-up is found to be higher for the curved seawall model (GS). The variations of relative run-up (R_u/H) as a function of *d/L* for models (VW) and (GS) with their toe in a slightly lesser water depth of 0.34m are plotted in Fig. 3(b), for various *H/d* values of 0.147 to 0.529. The results show that model (GS) experiences higher run-up with a decrease in the water depth. This is due to the shoaling of waves while progressing over the toe of the model and becomes steeper. Thus, the curvature of the model (GS) facilitates more energy available for the wave run-up. Further, as the shoreward surface tends to become vertical, the pressure exerted on the wall is also higher. A closer examination of results shows that model (GS) experiences a run-up of about 30% higher compared to model (VW).

B. Run-up under random waves

The variations of relative run-up (R_u/H_s) as a function of d/L_p for models (VW) and (GS) with their toe in a water depth of 0.46m are plotted in Fig. 4(a)**,** for H_s/d values of 0.108, 0.217 and 0.304. The R_u/H_s in general is found to decrease with an increase in d/L_p. A comparison of the results for models (VW) and (GS) exhibit that run-up is found to be higher for the curved seawall model (GS). The variations of relative run-up (R_u/H) as a function of *d/L* for models (VW) and (GS) with their toe in a slightly lesser water depth of 0.34m are plotted in Fig. 4(b), for various *H/d* values of 0.147, 0.297 and 0.412. The results show that model (GS) experiences higher run-up with a decrease in the water depth. This is due to the shoaling of waves while progressing over the toe of the model and becomes steeper. A closer examination of results shows that model (GS) experiences a run-up of about 55% higher compared to model (VW).

The comparisons of variations in the relative run-up for random and regular waves on both the seawalls are shown in Fig. 5(a) and (b). It is found that the run-up due to regular waves are slightly higher then that due to random waves.

C. Run-up under cnoidal waves

The variations of relative run-up (R_u/H) as a function of *d/L* for models (VW) and (GS) with their toe in a water depth of 0.46m for U_r ranging between 3.6 – 229.1 are plotted in Fig. 6(a). The (R_u/H) is found to decrease with an increase in *d/L*. A comparison of the results for models (VW) and (GS) exhibit that run-up is found to be higher for the curved seawall model (GS). The variations of relative run-up (R_u/H) as a function of *d/L* for models (VW) and (GS) with their toe in a water depth of 0.34m for U_r ranging between 4.8 – 301.7 are plotted in Fig. 6(b). The results show that model (GS) experiences higher run-up with a decrease in the water depth, because of the reasons said earlier. As the long will have more energy and hence the run-up is also high. A closer examination of results shows that model (GS) experiences a run-up of about 25% higher compared to model (VW).

The results show clearly that the shape of the curved seawall model (GS) is not adequate in directing the wave run-up more towards the ocean by the wave of dissipation, there by leading to an increase in the run-up. The results here in presented are only limited, as the test on two other re-curved seawalls have yielded favourable results towards the reduction in the run-up and there by their crest elevation, which will be reported else where.

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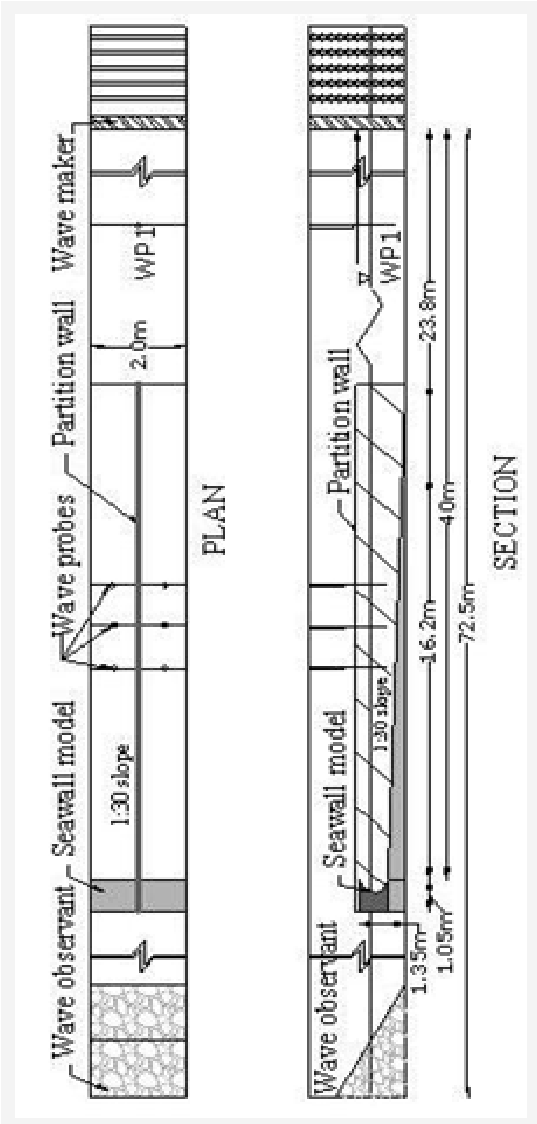

Fig. 2 The test set up in the flume both in plan and sectional elevation

IV. Conclusions

The curvature of model (GS) is found inadequate in directing the wave run-up towards the ocean, there by leading to an increase in the run-up by about 30% compared to that for the vertical seawall model under regular waves, similarly increase in the run-up on model (GS) compared to that on model (VW), under random and cnoidal waves are 55% and 45% respectively.

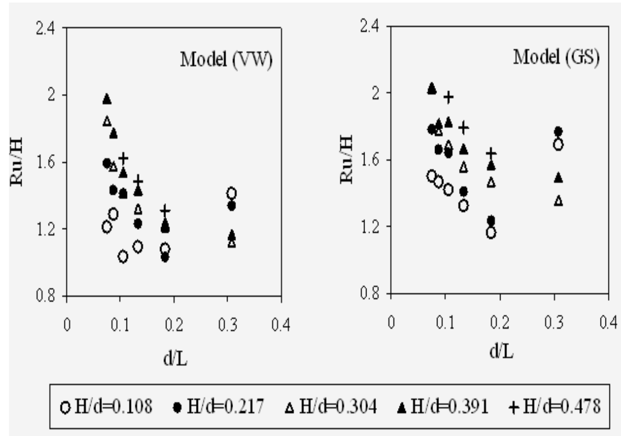

Fig. 3(a). The variation of run-up (R_u/H) with d/L for various H/d ratios with their toe in a water depth of 0.46m, under regular waves

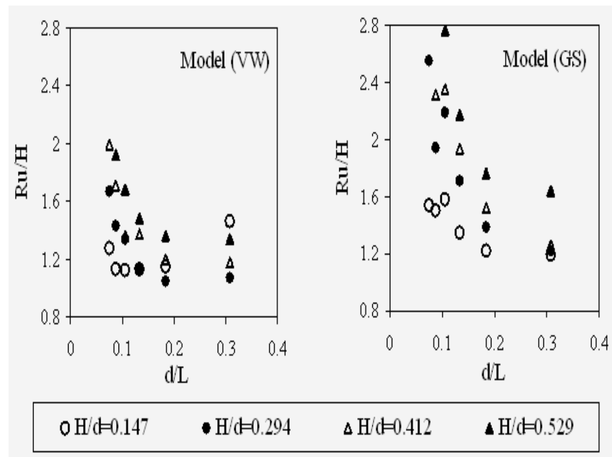

Fig. 3(b). The variation of run-up (R_u/H) with d/L for various H/d ratios with their toe in a water depth of 0.34m, under regular waves

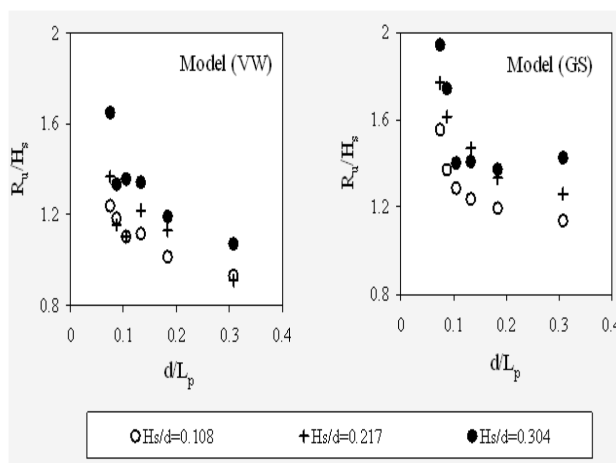

Fig. 4(a). The variation of run-up (R_u/H) with d/L_p for various H_s/d ratios with their toe in a water depth of 0.46m, under random waves

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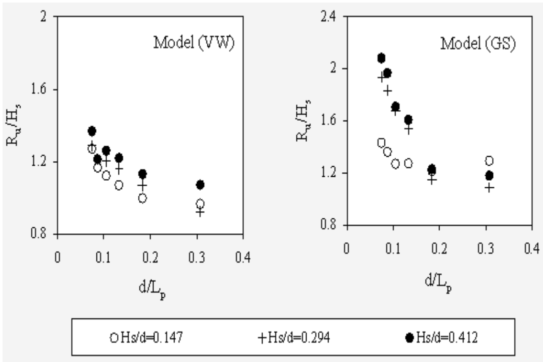

Fig. 4(b). The variation of run-up (R_u/H) with d/L_p for various H_s/d ratios with their toe in a water depth of 0.34m, under random waves

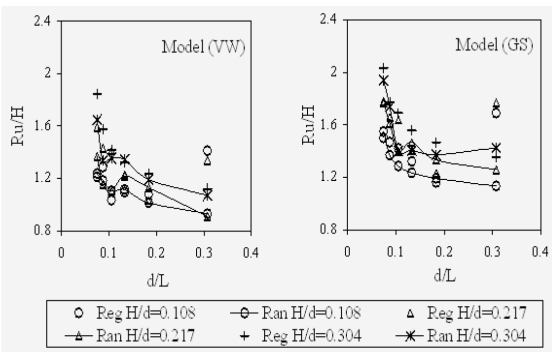

Fig. 5(a). The comparison of variation in the relative run-up (R_u/H) under regular and random waves for varioush d/L_p and H_s/d ratios in the water depth of 1.0m.

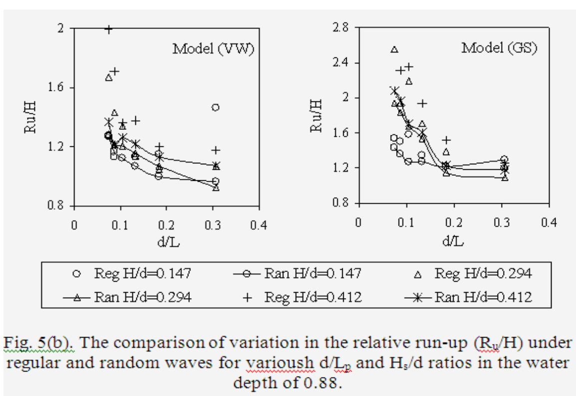

Fig. 5(b). The comparison of variation in the relative run-up (R_u/H) under regular and random waves for varioush d/L_p and H_s/d ratios in the water depth of 0.88.

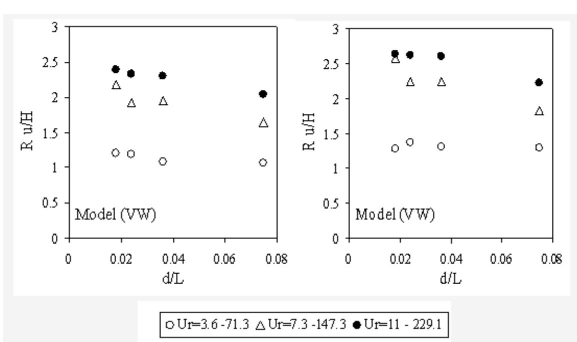

Fig. 6(a). The variation of run-up (Ru/H) with d/L for various Ur in the water depth of 1.0m, under cnoidal waves

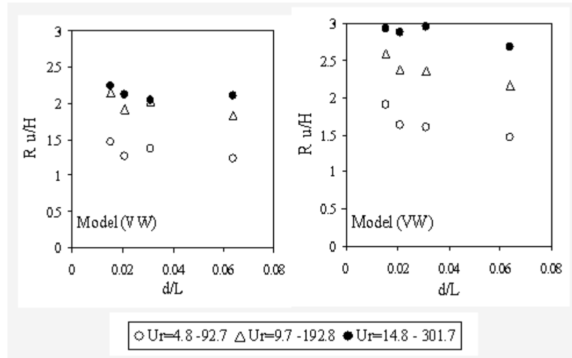

Fig. 6(b). The variation of run-up (Ru/H) with d/L for various Ur in the water depth of 0.88m, under cnoidal waves

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